

## **SMART DSL SYSTEMS FOR LDSL**

### **Related Applications**

[0001] The present invention claims priority to U.S. Provisional Application Nos. 60/426,796 filed November 18, 2002, the contents of which is incorporated herein by reference in their entirety.

[0002] This application is related to copending U.S. Patent Applications titled "SYSTEM AND METHOD FOR SELECTABLE MASK FOR LDSL," (Attorney Docket No. 56162.000456) which claims priority to U.S. Provisional Patent Application No. 60/441,351, "ENHANCED SMART DSL FOR LDSL," (Attorney Docket No. 56162.000483) which claims priority to U.S. Provisional Application No. 60/488,804 filed July 22, 2003, "ENHANCED SMART DSL FOR LDSL," (Attorney Docket No. 56162.000484) which claims priority to U.S. Provisional Application No. 60/488,804 filed July 22, 2003 and "POWER SPECTRAL DENSITY MASKS FOR IMPROVED SPECTRAL COMPATIBILITY" (Attorney Docket No. 56162.000485) which claims priority to U.S. Provisional Application No. 60/491,268 filed July 31, 2003, all filed concurrently herewith.

### **BACKGROUND OF THE INVENTION**

#### **Field of the Invention**

[0003] This invention relates to digital subscriber lines (DSL) and to smart systems for implementing Long reach Digital Subscriber Lines (LDSL).

#### **Description of Related Art**

[0004] High level procedures for meeting stated objectives for Long reach Digital Subscriber Line (LDSL) transmissions are disclosed. Some objectives for LDSL have been defined in publications available from standards organizations such as the International Telecommunications Union (ITU). For example, ITU publications OC-041R1, OC-045, OC-073R1, OJ-030, OJ-036, OJ-060, OJ-061, OJ-062, OJ-200R1, OJ-200R2, OJ-201, OJ-60R1, OJ-60R2 and OJ-210 set forth some LDSL

objectives. Other objectives, standards and criteria for LDSL are also possible and may be accommodated by the disclosed inventions.

[0005] One LDSL target objective is to achieve a minimum payload transmission of 192 kb/s downstream and 96 kb/s upstream on loops having an equivalent working length of 18 kft 26 gauge cable in a variety of loop and noise conditions. One difficulty in achieving these target transmission rates is the occurrence of crosstalk noise.

[0006] The crosstalk noise environments that may occur for the above bit rate target objective are varied. For example, noise environments may include Near-end cross talk (NEXT), Far-end cross talk (FEXT), disturbance from Integrated Services Digital Networks (ISDN), High Speed Digital Subscriber Lines (HDSL), SHDSL, T1, and Self-disturbances at both the Central Office (CO) and Customer Premise Equipment (CPE) ends. NEXT from HDSL and SHDSL tend to limit the performance in the upstream channel, while NEXT from repeatered T1 AMI systems tend to severely limit the downstream channel performance. An additional source of noise is loops containing bridged taps that degrade performance on an Asymmetric Digital Subscriber Line (ADSL) downstream channel more so than the upstream channel.

[0007] Another drawback of existing systems is that it appears very difficult to determine a single pair of Upstream and Downstream masks that will maximize the performance against any noise-loop field scenario, while ensuring spectral compatibility and, at the same time, keeping a desirable balance between Upstream and Downstream rates.

[0008] One approach for LDSL relies on different Upstream and Downstream masks exhibiting complementary features. Realistically, all these chosen masks are available on any LDSL Platform. At the modem start up, based on a certain protocol, the best Upstream-Downstream pair of masks is picked up. Whether the best pair is manually chosen at the discretion of the operator, or automatically selected, this concept is identified as "smart DSL for LDSL".

[0009] There are many reasons to implement smart DSL. For example, non-smart DSL systems may implement a single mask for upstream and downstream transmissions. A drawback with this approach is that the use of a single mask may prevent LDSL service in areas of the United States dominated by T1 noise.

[0010] In addition, the use of a single mask is a drawback because the existence of other spectrally compatible masks cannot be ruled out. LDSL service providers will want to have access to an array of mask/tools provided they are spectrally compatible. Service providers may decide to use only one mask according to the physical layer conditions, or any combination of masks for the same or other reasons.

[0011] Another advantage of Smart DSL is that it is a good way to handle providing LDSL services in different countries. For example, so far, LDSL work has focused on SBC requirements. As a result, it is risky of, for example, a US-based LDSL provider to rely on the ability to apply any masks that pass SBC tests to Europe, China or Korea. LDSL is a difficult project and essential for all the countries. Therefore, any scheme for LDSL standardization that takes into account merely SBC physical layer and cross talk requirements may jeopardize the ADSL reach extension in non-standard LDSL countries. Other drawbacks of current systems also exist.

#### SUMMARY OF THE INVENTION

[0012] A “Smart DSL System” for addressing the performance objectives of LDSL and examples of smart systems for LDSL are disclosed.

[0013] In accordance with embodiments of the invention, there is disclosed a method for implementing smart DSL for LDSL systems. Embodiments of the method may comprise presenting a number of spectral masks that are available on the LDSL system, and selecting from the number of spectral masks an upstream mask and a downstream mask wherein the upstream mask and the downstream mask exhibit complimentary features.

[0014] In some embodiments the method may further comprise selecting the upstream mask and the downstream mask during a modem start up period. Still further, embodiments of the invention may comprise selecting the upstream mask and the downstream mask manually or automatically.

[0015] In accordance with some embodiments of the invention, there is disclosed a method for implementing smart DSL for LDSL systems. In some embodiments, the method may comprise defining a candidate system to be implemented by an LDSL system, optimizing criteria associated with the candidate system, and selecting a candidate system to implement in an LDSL system.

[0016] In accordance with some embodiments of the invention, the method may further comprise determining features of upstream and downstream transmission. The method may further comprise determining one or more of: cut-off frequencies, side lobe shapes, overlap, partial overlap or FDD characteristics.

[0017] In some embodiments, the method may further comprise optimizing criteria associated with the candidate system to fulfill upstream and downstream performance targets and selecting a spectral mask for use with upstream or downstream transmission.

[0018] In accordance with some embodiments of the invention there is provided a method for implementing smart DSL for LDSL systems. In some embodiments the method may comprise selecting a spectral mask based upon performance criteria, and activating the selected spectral mask based at least one of customer premise or central office capabilities.

[0019] In accordance with further aspects of the invention, the method may further comprise selecting the spectral mask is performed manually or automatically. Other advantages and features of the invention are discussed below.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0020] Figure 1 is a graph illustrating U1 and D1 PSD masks, peak values;

[0021] Figure 2 is a graph illustrating U2 and D2 PSD masks, peak values;

[0022] Figure 3 is a graph illustrating U3 and D3 PSD templates, average values;

- [0023] Figure 4 is a bar chart illustrating upstream rate, noise case #1, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0024] Figure 5 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0025] Figure 6 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0026] Figure 7 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0027] Figure 8 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0028] Figure 9 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0029] Figure 10 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0030] Figure 11 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0031] Figure 12 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0032] Figure 13 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0033] Figure 14 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0034] Figure 15 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0035] Figure 16 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0036] Figure 17 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, NON EC Smart LDSL;

- [0037] Figure 18 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0038] Figure 19 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, NON EC Smart LDSL;
- [0039] Figure 20 is a bar chart illustrating upstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL;
- [0040] Figure 21 is a bar chart illustrating upstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL;
- [0041] Figure 22 is a bar chart illustrating upstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL;
- [0042] Figure 23 is a bar chart illustrating upstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL;
- [0043] Figure 24 is a bar chart illustrating upstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL;
- [0044] Figure 25 is a bar chart illustrating upstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL;
- [0045] Figure 26 is a bar chart illustrating upstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL;
- [0046] Figure 27 is a bar chart illustrating upstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL;
- [0047] Figure 28 is a bar chart illustrating downstream rate, noise case #1, ADSL2, M OJ-074, EC Smart LDSL;
- [0048] Figure 29 is a bar chart illustrating downstream rate, noise case #2, ADSL2, M OJ-074, EC Smart LDSL;
- [0049] Figure 30 is a bar chart illustrating downstream rate, noise case #3, ADSL2, M OJ-074, EC Smart LDSL;
- [0050] Figure 31 is a bar chart illustrating downstream rate, noise case #4, ADSL2, M OJ-074, EC Smart LDSL;

[0051] Figure 32 is a bar chart illustrating downstream rate, noise case #5, ADSL2, M OJ-074, EC Smart LDSL;

[0052] Figure 33 is a bar chart illustrating downstream rate, noise case #6, ADSL2, M OJ-074, EC Smart LDSL;

[0053] Figure 34 is a bar chart illustrating downstream rate, noise case #7, ADSL2, M OJ-074, EC Smart LDSL;

[0054] Figure 35 is a bar chart illustrating downstream rate, noise case #T1, ADSL2, M OJ-074, EC Smart LDSL;

[0055] Figure 36 illustrates one option to automatically select a pair of masks in a smart DSL system

[0056] Figure 37 illustrates another option to automatically select a pair of masks in a smart DSL system;

[0057] Figure 38 illustrates a “CP decides” sequence based on G.992.3;

[0058] Figure 39 illustrates a “CO decides” sequence based on G.992.3; and

[0059] Figure 40 illustrates a “CP overruled by CO” sequence;

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

##### **[0060] Smart DSL Concept for LDSL.**

[0061] This section defines a Smart DSL concept for LDSL. In some embodiments, operating with smart DSL systems for LDSL may include the below listed steps. The first and second steps may be completed, in some embodiments, during a standardization process and other steps may be performed during a modem’s handshake/initialization phase in order to optimize the performance for any type of loops and noises.

##### **[0062] Step 1. Smart DSL Systems members for LDSL (S).**

[0063] In some embodiments it is preferable to complete step 1 during standardization processes. Alternatively, step 1 may be performed off line, for example, if no standardization is at stake.

[0064] In some embodiments, the first step consists of defining candidate systems that aim to be picked up based on optimization criteria defined below. Typically, these candidate systems may exhibit sufficient versatility features for both Upstream and Downstream spectra, such as cut off frequencies, side lobes shapes, overlap, partial overlap, FDD characteristics, etc.

[0065] In some embodiments it may be desirable for candidate systems to also meet additional constraints. For example, an additional constraint may be that no new channel coding scheme should be considered in the candidate systems. In this manner, smart DSL systems in accordance with the invention exhibit several degrees of freedom that are summarized in what follows by parameter set S.

**[0066] Step 2. Optimization criteria (C):**

[0067] In some embodiments, it is preferable that the second step be completed during the standardization process. Alternatively, the second step may be completed off line if no standardization is at stake.

[0068] The second step comprises defining optimization criteria. Optimization criteria drive smart DSL systems members definition and, of course, the performance outcomes. For some embodiments, optimization criteria (C ) may be summarized as covering Upstream and Downstream performance targets. In addition, optimization criteria may cover the margin within which performance targets should be met, such as, whether the deployment is Upstream or Downstream limited. The last point is important since often, in order to keep the optimization process simple priority should be given to Upstream or Downstream channels.

[0069] In some embodiments, optimization criteria may also comprise spectral compatibility requirements. This criteria may also include assumptions about neighboring services. Other optimization criteria are also possible.

**[0070] Step 3. Choice of an optimal system amongst the smart DSL systems candidates (S\*).**

[0071] In some embodiments it may be preferable to complete step 3 during handshake/initialization. Completing step 3 during handshake/initialization may



enable better handling of any type of loops and noise/cross talk conditions. Alternatively, this step could be completed off line, for example, if the operator has accurate prior knowledge of loops and noise conditions.

**[0072]** In some embodiments, completion of step 3 may be as simple as picking up one of two masks already defined. In other embodiments, completion of step 3 may comprise tuning a continuous parameter such as a cut off frequency. Other methods of completing step 3 are also possible.

**[0073]** In some embodiments, the outcome of step 3 may comprise an optimal system ( $S^*$ ) that will be run by the modem in the conditions that lead to its optimality.

**[0074] Two Examples of Smart DSL system for LDSL, based on SBC requirements.**

**[0075] Example 1: Definition of the Masks to be used in the two smart systems.**

**[0076]** Three Upstream masks U1, U2, U3 and three Downstream masks D1, D2, D3 are used in what follows to define embodiments of smart systems. U1 (dashed line) and D1 (solid line) masks are plotted in Figure 1. Note that in this section the masks for peak values are defined. As defined by some standards, the PSD templates, or average PSD values, are 3.5 dB lower than the mask values. Tables 1 and 2 show some values for U1 and D1 (respectively) according to some embodiments of the invention.

| Frequency Band $f$ (kHz) | Equation for the PSD <u>mask</u> (dBm/Hz)  |
|--------------------------|--|
| $0 < f \leq 4$           | -97.5, with max power in the in 0-4 kHz band of +15 dBm  |
| $4 < f \leq 25.875$      | $-92.5 + 23.43 \times \log_2(f/4)$ ;   |
| $25.875 < f \leq 60.375$ | -29.0  |
| $60.375 < f \leq 90.5$   | $-34.5 - 95 \times \log_2(f/60.375)$   |
| $90.5 < f \leq 1221$     | -90  |
| $1221 < f \leq 1630$     | -99.5 peak, with max power in the $[f, f+1 \text{ MHz}]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm |
| $1630 < f \leq 11\,040$  | -99.5 peak, with max power in the $[f, f+1 \text{ MHz}]$ window of -50 dBm                                     |

Table 1. U1 PSD Mask Definition, peak values

| Frequency Band $f$ (kHz)  | Equation for the PSD <u>mask</u> (dBm/Hz)  |
|---------------------------|--|
| $0 < f \leq 4$            | -97.5, with max power in the in 0-4 kHz band of +15 dBm  |
| $4 < f \leq 25.875$       | $-92.5 + 20.79 \times \log_2(f/4)$   |
| $25.875 < f \leq 81$      | -36.5  |
| $81 < f \leq 92.1$        | $-36.5 - 70 \times \log_2(f/81)$   |
| $92.1 < f \leq 121.4$     | -49.5  |
| $121.4 < f \leq 138$      | $-49.5 + 70 \times \log_2(f/121.4)$  |
| $138 < f \leq 353.625$    | $-36.5 + 0.0139 \times (f - 138)$  |
| $353.625 < f \leq 569.25$ | -33.5  |
| $569.25 < f \leq 1622.5$  | $-33.5 - 36 \times \log_2(f/569.25)$   |
| $1622.5 < f \leq 3093$    | -90  |
| $3093 < f \leq 4545$      | -90 peak, with maximum power in the $[f, f+1 \text{ MHz}]$ window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm |
| $4545 < f \leq 11\,040$   | -90 peak, with maximum power in the $[f, f+1 \text{ MHz}]$ window of -50 dBm                                       |

Table 2. D1 PSD Mask Definition, peak values

[0077] According to some embodiments of the invention U2 (dashed line) and D2 (solid line) spectrum masks may be plotted as shown in Figure 2. Note that, as above, the masks for peak values are defined. The PSD templates, or average PSD

values, are 3.5 dB lower than the mask values. Tables 3 and 4 show some values for U2 and D2 (respectively) in accordance with some embodiments of the invention.

| Frequency Band $f$ (kHz) | Equation for the PSD <u>mask</u> (dBm/Hz)  |
|--------------------------|--|
| $0 < f \leq 4$           | -97.5, with max power in the in 0-4 kHz band of +15 dBm  |
| $4 < f \leq 25.875$      | $-92.5 - 22.5 \times \log_2(f/4)$ ;  |
| $25.875 < f \leq 86.25$  | -30.9  |
| $86.25 < f \leq 138.6$   | $-34.5 - 95 \times \log_2(f/86.25)$  |
| $138.6 < f \leq 1221$    | -99.5  |
| $1221 < f \leq 1630$     | -99.5 peak, with max power in the $[f, f + 1 \text{ MHz}]$ window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm |
| $1630 < f \leq 11\,040$  | -99.5 peak, with max power in the $[f, f + 1 \text{ MHz}]$ window of -50 dBm                                     |

**Table 3. U2 Mask Definition, peak values**

| Starting Frequency (kHz) | Starting PSD mask value (dBm/Hz) |
|--------------------------|----------------------------------|
| 0.000000                 | -98.000000                       |
| 3.990000                 | -98.000000                       |
| 4.000000                 | -92.500000                       |
| 80.000000                | -72.500000                       |
| 120.740000               | -47.500000                       |
| 120.750000               | -37.800000                       |
| 138.000000               | -36.800000                       |
| 276.000000               | -33.500000                       |
| 677.062500               | -33.500000                       |
| 956.000000               | -62.000000                       |
| 1800.000000              | -62.000000                       |
| 2290.000000              | -90.000000                       |
| 3093.000000              | -90.000000                       |
| 4545.000000              | -110.000000                      |
| 12000.000000             | -110.000000                      |

**Table 4. D2 Mask Definition, peak values**

[0078] Similarly, tables 5 and 6 give the breakpoints of U3 and D3 PSD Templates (*average values*) in accordance with some embodiments of the invention. Figure 3 shows U3 (dashed line) and D3 (solid line) according to some embodiments of the invention.

| Frequency<br>[KHz] | Nominal Upstream PSD<br>[dBm/Hz] |
|--------------------|----------------------------------|
| 0                  | -101.5                           |
| 4                  | -101.5                           |
| 4                  | -96                              |
| 25.875             | -36.30                           |
| 103.5              | -36.30                           |
| 164.1              | -99.5                            |
| 1221               | -99.5                            |
| 1630               | -113.5                           |
| 12000              | -113.5                           |

**Table 5. U3 Spectrum PSD Template, average values**

| Frequency<br>[kHz] | Nominal Downstream PSD<br>[dBm/Hz] |
|--------------------|------------------------------------|
| 0                  | -101.5                             |
| 4                  | -101.5                             |
| 4                  | -96                                |
| 80                 | -76                                |
| 138                | -47.5                              |
| 138                | -40                                |
| 276                | -37                                |
| 552                | -37                                |
| 956                | -65.5                              |
| 1800               | -65.5                              |
| 2290               | -93.5                              |
| 3093               | -93.5                              |
| 4545               | -113.5                             |
| 12000              | -113.5                             |

**Table 6. D3 Spectrum PSD Template, average values**

**[0079] Smart system scenario detection.**

[0080] In this scenario, it is assumed that the Smart LDSL system has the capability either to analyze *a priori* the cross talk/physical layer conditions, or to pick up a mask after testing all of them based on performance and spectral compatibility criteria. Under this feature, all the modems located in the same area will detect the same type of cross talk/impairments. Therefore, the worst case catastrophic scenario based on the use of all the possible masks at any location happens to be a completely unrealistic view for a genuine smart system. This feature was incorporated with success in the already deployed smart enhanced Annex C for Japan.

**[0081] Example 1: NON EC Smart LDSL**

**[0082] Definition**

[0083] In this exemplary embodiment, a first smart system makes use of U1, U2, U3 and D1, D3 masks. According to the features of all these masks, no Echo canceller

is required by this embodiment of a smart system that will be identified as NON EC Smart LDSL.

**[0084] Simulation Results**

**[0085]** Tables 7 and 8 gives the ADSL2 upstream and downstream performance for calibration purposes.

|       |          | upstream   |        |        |        |        |        |        |      |
|-------|----------|------------|--------|--------|--------|--------|--------|--------|------|
|       |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |      |
|       |          | Self Noise | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1   |
| ADSL2 | xDSL 10  | 1107       | 1107   | 596    | 294    | 305    | 570    | 646    | 1133 |
|       | xDSL 11  | 884        | 884    | 319    | 120    | 130    | 291    | 361    | 894  |
|       | xDSL 12  | 846        | 846    | 275    | 90     | 102    | 248    | 314    | 854  |
|       | xDSL 13  | 692        | 692    | 142    | 48     | 54     | 99     | 163    | 697  |
|       | xDSL 160 | 969        | 969    | 406    | 141    | 157    | 380    | 452    | 986  |
|       | xDSL 165 | 925        | 925    | 360    | 116    | 130    | 330    | 404    | 944  |
|       | xDSL 170 | 881        | 881    | 313    | 94     | 106    | 287    | 354    | 897  |
|       | xDSL 175 | 837        | 837    | 269    | 78     | 89     | 243    | 306    | 851  |
|       | xDSL 180 | 798        | 798    | 225    | 63     | 74     | 202    | 266    | 805  |
|       | xDSL 185 | 755        | 755    | 185    | 51     | 60     | 162    | 224    | 764  |

**Table 7. ADSL2 Upstream Channel performance**

|       |          | downstream |        |        |        |        |        |        |     |
|-------|----------|------------|--------|--------|--------|--------|--------|--------|-----|
|       |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|       |          | Self Noise | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| ADSL2 | xDSL 10  | 298        | 298    | 305    | 328    | 326    | 307    | 162    | 170 |
|       | xDSL 11  | 0          | 0      | 0      | 0      | 0      | 0      | 0      | 0   |
|       | xDSL 12  | 0          | 0      | 0      | 0      | 0      | 0      | 0      | 0   |
|       | xDSL 13  | 0          | 0      | 0      | 0      | 0      | 0      | 0      | 0   |
|       | xDSL 160 | 300        | 300    | 303    | 323    | 321    | 303    | 88     | 91  |
|       | xDSL 165 | 201        | 201    | 203    | 224    | 224    | 207    | 43     | 49  |
|       | xDSL 170 | 125        | 125    | 113    | 141    | 140    | 123    | 8      | 13  |
|       | xDSL 175 | 59         | 66     | 57     | 74     | 74     | 63     | 0      | 0   |
|       | xDSL 180 | 0          | 8      | 12     | 17     | 17     | 12     | 0      | 0   |
|       | xDSL 185 | 0          | 0      | 0      | 0      | 0      | 0      | 0      | 0   |

**Table 8. ADSL2 Downstream Channel performance**

**[0086]** Tables 9 and 10 display the results of the Modified OJ-074. These results may be taken as references for LDSL.

|          |          | upstream |        |        |        |        |        |        |     |
|----------|----------|----------|--------|--------|--------|--------|--------|--------|-----|
|          |          | case 1   | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|          |          | Self Ne  | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| M OJ-074 | xDSL 10  | 839      | 841    | 488    | 300    | 315    | 458    | 510    | 844 |
|          | xDSL 11  | 667      | 667    | 312    | 144    | 159    | 283    | 332    | 669 |
|          | xDSL 12  | 622      | 623    | 270    | 111    | 124    | 242    | 289    | 624 |
|          | xDSL 13  | 496      | 496    | 157    | 59     | 69     | 136    | 176    | 497 |
|          | xDSL 160 | 709      | 710    | 353    | 174    | 191    | 324    | 374    | 711 |
|          | xDSL 165 | 675      | 675    | 319    | 145    | 161    | 291    | 340    | 677 |
|          | xDSL 170 | 641      | 641    | 287    | 120    | 134    | 259    | 307    | 642 |
|          | xDSL 175 | 606      | 606    | 255    | 101    | 110    | 227    | 275    | 608 |
|          | xDSL 180 | 572      | 572    | 224    | 80     | 92     | 198    | 243    | 573 |
|          | xDSL 185 | 537      | 537    | 195    | 66     | 76     | 169    | 212    | 539 |

**Table 9. M OJ-074 Upstream Channel Performance Results**

|          |          | downstream |        |        |        |        |        |        |     |
|----------|----------|------------|--------|--------|--------|--------|--------|--------|-----|
|          |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|          |          | Self Ne    | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| M OJ-074 | xDSL 10  | 2396       | 1659   | 1784   | 2023   | 1991   | 1616   | 224    | 436 |
|          | xDSL 11  | 997        | 407    | 431    | 861    | 892    | 358    | 0      | 79  |
|          | xDSL 12  | 1202       | 643    | 622    | 974    | 969    | 546    | 0      | 48  |
|          | xDSL 13  | 855        | 398    | 449    | 696    | 776    | 350    | 0      | 52  |
|          | xDSL 160 | 2048       | 1333   | 1413   | 1752   | 1725   | 1268   | 150    | 331 |
|          | xDSL 165 | 1788       | 1086   | 1179   | 1527   | 1518   | 1027   | 92     | 261 |
|          | xDSL 170 | 1553       | 875    | 933    | 1326   | 1332   | 809    | 53     | 205 |
|          | xDSL 175 | 1343       | 754    | 755    | 1145   | 1163   | 648    | 25     | 152 |
|          | xDSL 180 | 1147       | 633    | 694    | 985    | 1011   | 579    | 4      | 111 |
|          | xDSL 185 | 978        | 529    | 608    | 840    | 872    | 500    | 0      | 76  |

**Table 10. M OJ-074 Upstream Channel Performance Results**

[0087] Tables 11 and 12 give the results of NON EC Smart LDSL system.

|              |          | upstream |        |        |        |        |        |        |     |
|--------------|----------|----------|--------|--------|--------|--------|--------|--------|-----|
|              |          | case 1   | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|              |          | Self Net | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| NON EC SMART | xDSL 10  | 839      | 841    | 488    | 310    | 324    | 458    | 510    | 851 |
|              | xDSL 11  | 667      | 667    | 312    | 179    | 196    | 283    | 332    | 673 |
|              | xDSL 12  | 622      | 623    | 270    | 146    | 157    | 242    | 289    | 628 |
|              | xDSL 13  | 496      | 496    | 176    | 102    | 110    | 142    | 176    | 500 |
|              | xDSL 160 | 709      | 710    | 353    | 206    | 219    | 324    | 374    | 716 |
|              | xDSL 165 | 675      | 675    | 319    | 182    | 195    | 291    | 340    | 681 |
|              | xDSL 170 | 641      | 641    | 287    | 152    | 168    | 259    | 307    | 646 |
|              | xDSL 175 | 606      | 606    | 255    | 136    | 145    | 227    | 275    | 611 |
|              | xDSL 180 | 572      | 572    | 226    | 122    | 130    | 198    | 243    | 577 |
|              | xDSL 185 | 537      | 537    | 200    | 108    | 116    | 169    | 212    | 542 |

**Table 11. NON EC Smart LDSL Upstream Channel Performance Results**

|              |          | downstream |        |        |        |        |        |        |     |
|--------------|----------|------------|--------|--------|--------|--------|--------|--------|-----|
|              |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|              |          | Self Net   | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| NON EC SMART | xDSL 10  | 2615       | 1711   | 1946   | 2148   | 2169   | 1679   | 224    | 572 |
|              | xDSL 11  | 1060       | 407    | 445    | 902    | 958    | 358    | 0      | 135 |
|              | xDSL 12  | 1265       | 643    | 634    | 998    | 1025   | 546    | 0      | 105 |
|              | xDSL 13  | 885        | 398    | 449    | 705    | 816    | 350    | 0      | 79  |
|              | xDSL 160 | 2156       | 1333   | 1466   | 1797   | 1816   | 1268   | 150    | 429 |
|              | xDSL 165 | 1885       | 1086   | 1222   | 1572   | 1604   | 1027   | 92     | 349 |
|              | xDSL 170 | 1639       | 875    | 967    | 1370   | 1413   | 809    | 53     | 278 |
|              | xDSL 175 | 1418       | 754    | 782    | 1187   | 1237   | 648    | 25     | 220 |
|              | xDSL 180 | 1213       | 633    | 720    | 1025   | 1079   | 579    | 4      | 169 |
|              | xDSL 185 | 1034       | 529    | 629    | 877    | 932    | 500    | 0      | 126 |

**Table 12. NON EC Smart LDSL Downstream Channel Performance Results**

[0088] Tables 13 and 14 give the selected Upstream and Downstream masks by the smart system. These tables confirm that, for this embodiment, a single mask can't handle all the noise scenarios and all the loops.



|                 |          | Upstream |        |        |        |        |        |        |    |
|-----------------|----------|----------|--------|--------|--------|--------|--------|--------|----|
|                 |          | case 1   | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |    |
|                 |          | Self Net | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1 |
| selection index | xDSL 10  | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                 | xDSL 11  | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                 | xDSL 12  | 3        | 3      | 3      | 1      | 2      | 3      | 3      | 3  |
|                 | xDSL 13  | 3        | 3      | 2      | 1      | 1      | 2      | 2      | 3  |
|                 | xDSL 160 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                 | xDSL 165 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                 | xDSL 170 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                 | xDSL 175 | 3        | 3      | 3      | 1      | 1      | 3      | 3      | 3  |
|                 | xDSL 180 | 3        | 3      | 2      | 1      | 1      | 3      | 3      | 3  |
|                 | xDSL 185 | 3        | 3      | 2      | 1      | 1      | 3      | 3      | 3  |

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

**Table 13. NON EC Smart LDSL: Upstream Selection Table**

|                 |          | Downstream |        |        |        |        |        |        |    |
|-----------------|----------|------------|--------|--------|--------|--------|--------|--------|----|
|                 |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |    |
|                 |          | Self Net   | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1 |
| selection index | xDSL 10  | 1          | 1      | 1      | 1      | 1      | 1      | 2      | 1  |
|                 | xDSL 11  | 1          | 2      | 1      | 1      | 1      | 2      | 1      | 1  |
|                 | xDSL 12  | 1          | 2      | 1      | 1      | 1      | 2      | 1      | 1  |
|                 | xDSL 13  | 1          | 2      | 2      | 1      | 1      | 2      | 1      | 1  |
|                 | xDSL 160 | 1          | 2      | 1      | 1      | 1      | 2      | 2      | 1  |
|                 | xDSL 165 | 1          | 2      | 1      | 1      | 1      | 2      | 2      | 1  |
|                 | xDSL 170 | 1          | 2      | 1      | 1      | 1      | 2      | 2      | 1  |
|                 | xDSL 175 | 1          | 2      | 1      | 1      | 1      | 2      | 2      | 1  |
|                 | xDSL 180 | 1          | 2      | 1      | 1      | 1      | 2      | 2      | 1  |
|                 | xDSL 185 | 1          | 2      | 1      | 1      | 1      | 2      | 1      | 1  |

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

**Table 14. NON EC Smart LDSL: Downstream Selection Table**

[0089] Tables 15 and 16 provide the performance improvement inherent to the NON EC Smart LDSL versus M OJ-074. As can be seen from the tables, this embodiment of a smart system performs better than the system disclosed in M OJ-074. This embodiment of a smart system compensates for the M OJ-074 Upstream channel weaknesses in the presence of SHDSL and HDSL.

| upstream difference with M OJ-074 |        |        |        |        |        |        |    |
|-----------------------------------|--------|--------|--------|--------|--------|--------|----|
| case 1                            | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |    |
| Self Net                          | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1 |
| 0                                 | 0      | 0      | 10     | 9      | 0      | 0      | 7  |
| 0                                 | 0      | 0      | 35     | 37     | 0      | 0      | 4  |
| 0                                 | 0      | 0      | 35     | 33     | 0      | 0      | 4  |
| 0                                 | 0      | 19     | 43     | 41     | 6      | 0      | 3  |
| 0                                 | 0      | 0      | 32     | 28     | 0      | 0      | 5  |
| 0                                 | 0      | 0      | 37     | 34     | 0      | 0      | 4  |
| 0                                 | 0      | 0      | 32     | 34     | 0      | 0      | 4  |
| 0                                 | 0      | 0      | 35     | 35     | 0      | 0      | 3  |
| 0                                 | 0      | 2      | 42     | 38     | 0      | 0      | 4  |
| 0                                 | 0      | 5      | 42     | 40     | 0      | 0      | 3  |

**Table 15. (NON EC SMART LDSL US rate – M OJ074 US rate)**

| downstream difference with M OJ-074 |        |        |        |        |        |        |     |
|-------------------------------------|--------|--------|--------|--------|--------|--------|-----|
| case 1                              | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
| Self Net                            | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| 219                                 | 52     | 162    | 125    | 178    | 63     | 0      | 136 |
| 63                                  | 0      | 14     | 41     | 66     | 0      | 0      | 56  |
| 63                                  | 0      | 12     | 24     | 56     | 0      | 0      | 57  |
| 30                                  | 0      | 0      | 9      | 40     | 0      | 0      | 27  |
| 108                                 | 0      | 53     | 45     | 91     | 0      | 0      | 98  |
| 97                                  | 0      | 43     | 45     | 86     | 0      | 0      | 88  |
| 86                                  | 0      | 34     | 44     | 81     | 0      | 0      | 73  |
| 75                                  | 0      | 27     | 42     | 74     | 0      | 0      | 68  |
| 66                                  | 0      | 26     | 40     | 68     | 0      | 0      | 58  |
| 56                                  | 0      | 21     | 37     | 60     | 0      | 0      | 50  |

**Table 16. (NON EC SMART LDSL DS rate – M OJ074 DS rate)**

[0090] Figures 4-19 show bar chart performance plots of ADSL2, non-EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases..

[0091] **EC Smart LDSL system**

[0092] **Definition**

[0093] As described above, a first exemplary smart system may make use of U1, U2, U3 and D1, D2, D3. In accordance with the features of all these masks, an Echo canceller may be advantageous when D2 is used. A second exemplary smart system may be identified as the EC Smart LDSL. For this embodiment, the Smart LDSL system may have the capability to analyze *a priori* the cross talk/physical layer

conditions for all the Smart LDSL modems located in the same area. In addition the system may detect the same type of cross talks/impairments and, therefore, the worst case self NEXT due to the Downstream mask D2 may only apply when this mask is used.

**[0094] EC Smart LDSL: Simulation results**

|                     |          | upstream |        |        |        |        |        |        |     |
|---------------------|----------|----------|--------|--------|--------|--------|--------|--------|-----|
|                     |          | case 1   | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|                     |          | Self Ne  | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| EC<br>SMART<br>LDSL | xDSL 10  | 839      | 841    | 488    | 310    | 324    | 458    | 456    | 423 |
|                     | xDSL 11  | 667      | 667    | 312    | 179    | 196    | 283    | 280    | 253 |
|                     | xDSL 12  | 622      | 623    | 270    | 146    | 157    | 242    | 239    | 214 |
|                     | xDSL 13  | 496      | 496    | 176    | 102    | 110    | 142    | 135    | 130 |
|                     | xDSL 160 | 709      | 710    | 353    | 206    | 219    | 324    | 321    | 291 |
|                     | xDSL 165 | 675      | 675    | 319    | 182    | 195    | 291    | 288    | 259 |
|                     | xDSL 170 | 641      | 641    | 287    | 152    | 168    | 259    | 256    | 229 |
|                     | xDSL 175 | 606      | 606    | 255    | 136    | 145    | 227    | 225    | 200 |
|                     | xDSL 180 | 572      | 572    | 226    | 122    | 130    | 198    | 195    | 168 |
|                     | xDSL 185 | 537      | 537    | 200    | 108    | 116    | 169    | 166    | 139 |

**Table 17. EC Smart LDSL Upstream Channel Performance Results**

|                     |          | Downstream |        |        |        |        |        |        |     |
|---------------------|----------|------------|--------|--------|--------|--------|--------|--------|-----|
|                     |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
|                     |          | Self Ne    | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| EC<br>SMART<br>LDSL | xDSL 10  | 2615       | 1711   | 1946   | 2148   | 2169   | 1679   | 381    | 719 |
|                     | xDSL 11  | 1060       | 407    | 445    | 902    | 958    | 358    | 54     | 193 |
|                     | xDSL 12  | 1265       | 643    | 634    | 998    | 1025   | 546    | 38     | 140 |
|                     | xDSL 13  | 885        | 398    | 449    | 705    | 816    | 350    | 18     | 80  |
|                     | xDSL 160 | 2156       | 1333   | 1466   | 1797   | 1816   | 1268   | 216    | 476 |
|                     | xDSL 165 | 1885       | 1086   | 1222   | 1572   | 1604   | 1027   | 140    | 388 |
|                     | xDSL 170 | 1639       | 875    | 967    | 1370   | 1413   | 809    | 86     | 308 |
|                     | xDSL 175 | 1418       | 754    | 782    | 1187   | 1237   | 648    | 62     | 237 |
|                     | xDSL 180 | 1213       | 633    | 720    | 1025   | 1079   | 579    | 28     | 181 |
|                     | xDSL 185 | 1034       | 529    | 629    | 877    | 932    | 500    | 20     | 127 |

**Table 18. EC Smart LDSL Downstream Channel Performance Results**

|                     |          | Upstream |        |        |        |        |        |        |    |
|---------------------|----------|----------|--------|--------|--------|--------|--------|--------|----|
|                     |          | case 1   | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |    |
|                     |          | Self Net | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1 |
| EC<br>SMART<br>LDSL | xDSL 10  | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                     | xDSL 11  | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                     | xDSL 12  | 3        | 3      | 3      | 1      | 2      | 3      | 3      | 3  |
|                     | xDSL 13  | 3        | 3      | 2      | 1      | 1      | 2      | 2      | 1  |
|                     | xDSL 160 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                     | xDSL 165 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                     | xDSL 170 | 3        | 3      | 3      | 2      | 2      | 3      | 3      | 3  |
|                     | xDSL 175 | 3        | 3      | 3      | 1      | 1      | 3      | 3      | 3  |
|                     | xDSL 180 | 3        | 3      | 2      | 1      | 1      | 3      | 3      | 2  |
|                     | xDSL 185 | 3        | 3      | 2      | 1      | 1      | 3      | 3      | 2  |

1 = ends at ~60KHz, 2 = ends at ~86KHz, 3 = ends at ~103KHz

**Table 19. EC Smart LDSL: Upstream Selection Table**

|                     |          | Downstream |        |        |        |        |        |        |    |
|---------------------|----------|------------|--------|--------|--------|--------|--------|--------|----|
|                     |          | case 1     | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |    |
|                     |          | Self Net   | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1 |
| EC<br>SMART<br>LDSL | xDSL 10  | 2          | 2      | 2      | 2      | 2      | 2      | 1      | 1  |
|                     | xDSL 11  | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 12  | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 13  | 2          | 3      | 3      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 160 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 165 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 170 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 175 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 180 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |
|                     | xDSL 185 | 2          | 3      | 2      | 2      | 2      | 3      | 1      | 1  |

1 = starts at ~ 120KHz ; 2 = starts at ~ 138KHz

**Table 20. EC Smart LDSL: Downstream Selection Table**

| upstream difference with M OJ-074 |        |        |        |        |        |        |      |
|-----------------------------------|--------|--------|--------|--------|--------|--------|------|
| case 1                            | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |      |
| Self Net                          | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1   |
| 0                                 | 0      | 0      | 10     | 9      | 0      | -54    | -421 |
| 0                                 | 0      | 0      | 35     | 37     | 0      | -52    | -416 |
| 0                                 | 0      | 0      | 35     | 33     | 0      | -50    | -410 |
| 0                                 | 0      | 19     | 43     | 41     | 6      | -41    | -367 |
| 0                                 | 0      | 0      | 32     | 28     | 0      | -53    | -420 |
| 0                                 | 0      | 0      | 37     | 34     | 0      | -52    | -418 |
| 0                                 | 0      | 0      | 32     | 34     | 0      | -51    | -413 |
| 0                                 | 0      | 0      | 35     | 35     | 0      | -50    | -408 |
| 0                                 | 0      | 2      | 42     | 38     | 0      | -48    | -405 |
| 0                                 | 0      | 5      | 42     | 40     | 0      | -46    | -400 |

**Table 21. (EC SMART LDSL US rate – M OJ074 US rate)**

| downstream difference with M OJ-074 |        |        |        |        |        |        |     |
|-------------------------------------|--------|--------|--------|--------|--------|--------|-----|
| case 1                              | case 2 | case 3 | case 4 | case 5 | case 6 | case 7 |     |
| Self Net                            | ADSL   | ISDN   | SHDSL  | HDSL   | MIX    | TIA    | T1  |
| 219                                 | 52     | 162    | 125    | 178    | 63     | 157    | 283 |
| 63                                  | 0      | 14     | 41     | 66     | 0      | 54     | 114 |
| 63                                  | 0      | 12     | 24     | 56     | 0      | 38     | 92  |
| 30                                  | 0      | 0      | 9      | 40     | 0      | 18     | 28  |
| 108                                 | 0      | 53     | 45     | 91     | 0      | 66     | 145 |
| 97                                  | 0      | 43     | 45     | 86     | 0      | 48     | 127 |
| 86                                  | 0      | 34     | 44     | 81     | 0      | 33     | 103 |
| 75                                  | 0      | 27     | 42     | 74     | 0      | 37     | 85  |
| 66                                  | 0      | 26     | 40     | 68     | 0      | 24     | 70  |
| 56                                  | 0      | 21     | 37     | 60     | 0      | 20     | 51  |

**Table 22. (EC SMART LDSL DS rate – M OJ074 DS rate)**

[0095] Figures 20-35 show bar chart performance plots of ADSL2, EC smart LDSL and the system disclosed in M OJ-074, for the above described noise cases.

#### [0096] Smart DSL Implementation based on ITU-T Recommendation G.992.3

##### [0097] Two steps

[0098] Deciding to access one of the mask amongst all the possible choices offered by a smart DSL platform may be facilitated by using a two step process in the following order:

[0099] (1) Masks Choice based on Performance/Physical layer status criterion: Smart functionality; and (2) Protocol to activate one particular mask based on CP/CO capabilities.

[00100]                   **Step (1): Mask Choice based on Performance/Physical layer Status: Smart Functionality.**

[00101]                   Figure 36 displays the org chart that describes the two selection modes inherent to smart DSL: manual or automatic.

[00102]                   The automatic selection may be completed in two different ways: by making use of the Line Probing capabilities of G.992.3 (LP Option) or by trying different masks up to the training and choosing at the end the best (Many Tests Option). Figure 37 gives the state diagram of the two approaches to automatically select a pair of mask for a smart DSL platform.

[00103]                   The LP option needs to complete the right loop of operations in figure 37 one time only. The Many tests option requires to complete the left loop of operations in figure 37 as many times as the number of available possibilities.

[00104]   **Step 2: Protocol to activate one mask based on CO / CP capabilities.**

[00105] This section discloses three protocol examples to activate one mask based on CO/CP capabilities.

[00106] **Option 1: CP decides**

[00107] Figure 38 describes the “CP decides” which mask is to be used sequence, based on G.992.3. CLR and CL allow CP and CO to signify their list of capabilities.

[00108] **Option 2: CO decides**

[00109] Figure 39 describes the “CO decides” which mask is to be used sequence, based on G.992.3, after being requested by the CP to do so. CLR and CL allow CP and CO to signify their list of capabilities.

[00110] **Option 3: CP is overruled by CO**

[00111] Figure 40 describes the “CO overrules CP” about which mask is to be used sequence, based on G.992.3, after CP has mentioned which mask is to be used . CLR and CL allow CP and CO to signify their list of capabilities.